# REPORT

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ON THE

# Lethbridge Northern Irrigation District

ALBERTA, CANADA

EDMONTON
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1920

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Hon. Charles Stewart,
*Premier,*
Province of Alberta, Canada.

Dear Sir—

I beg to transmit you herewith my report on the Lethbridge Northern Irrigation District, in which I have endeavoured to present and consider all facts bearing on the engineering, financial, and administrative problems involved, not solely as applied to the particular undertaking, but as related to the determination of general policies affecting the development of the agricultural resources of the Province of Alberta.

Yours respectfully,
George G. Anderson,
*Consulting Engineer.*

Member, Engineering Institute of Canada.
Member, Institution of Civil Engineers.
Member, American Society of Civil Engineers.

Edmonton, Alberta,
January 17, 1920.

91047

# REPORT

## ON THE

# LETHBRIDGE NORTHERN IRRIGATION DISTRICT

## ALBERTA, CANADA

The Lethbridge Northern Irrigation District has been created, under the provisions of The Irrigation District Act of Alberta, 1915. for the purpose of increasing the agricultural production of 97,531 acres, lying north of the Oldman River, in the vicinity of Lethbridge, by irrigation, utilizing the water supply of the Oldman River.

Field inspection has been made of all the territory embraced in the district, particular attention being paid to the general route of the main canal system, which was followed closely throughout nearly all of its entire length. In some short stretches, where access to the approximate location was not readily obtainable, the general character of the country in the immediate vicinity was closely observed, and altogether the inspection afforded a thorough knowledge of the conditions to be encountered in canal construction.

The irrigable area was also traversed fully, under favourable weather conditions, and all elements affecting the availability and adaptability of the district to irrigation conditions, as character of soil, slope, and uniformity of surface, etc., were duly noted.

Following upon that, investigation and study of the maps and plans of the system, as designed, have been made in the office of the Irrigation Branch of the Department of the Interior, at Calgary, under whose charge and supervision that work has been carried out during the preceding five years.

The records of the stream discharge of the Oldman River, also in charge of the Irrigation Branch, have been carefully studied, and it has been the endeavour to consider all features, affecting the general scope of the enterprise, thoroughly and in detail.

In the following report it will be the effort to present all the facts bearing upon the proposed development fully and thoroughly, in such detail as is unavoidably necessary, in order that the final conclusions on this important and far-reaching undertaking may clearly present themselves for consideration and determination.

The prime essential in an irrigation enterprise is that there shall be assurance, at all times, of an adequate water supply.

The canal capacity has been designed for a maximum irrigation requirement of one second foot for one hundred and twenty acres of land, to which has been added an allowance of 34 per cent. for all losses in transportation. On 97,531 acres irrigable, this would represent 813 second feet for irrigation needs, plus 34 per cent. of that volume—276 second feet—to cover canal losses, or a total of 1,089 second feet. The canal capacity below the siphon crossing of the Oldman River is designed for 1098 second feet.

An irrigation factor of 80 per cent. of the whole irrigable area is employed, in actual operation, that is to say, it is concluded that not to exceed 80 per cent. of the whole irrigable area will be under cultivation or calling for irrigation supply, at one time, in any one irrigation season.

That assumption is fairly warranted; but, for the immediate purpose of testing the adequacy of the water supply, the consideration will be based upon an irrigation demand of 100 per cent. of the irrigable area.

That total irrigation demand is represented by a net duty of water aggregating one and one-half acre feet per acre per season; that is to say, that the irrigable area will receive water equivalent to 18 inches in depth throughout the season.

That quantity would be distributed throughout the season in relation to the actual needs of the crop, in the amounts and periods as follows:—

| | Amt. | Period |
|---|---|---|
| May 1 to June 10 | 4.4 inches | 41 days |
| June 10 to July 15 | 7.0 " | 35 " |
| July 15 to August 20 | 4.4 " | 36 " |
| August 20 to September 30 | 2.2 " | 41 " |
| | 18.0 ins. | 153 days |

(See page 26 on Irrigation Surveys and Inspections 1916-17, Department of the Interior of Canada.)

That *net* irrigation supply is ample for crop requirements.

Just what it implies may be realized by brief consideration of the rainfall records of the district and farming results under natural conditions, i.e., "dry farming," in recent years.

Bumper wheat crops were secured in the Lethbridge Northern Irrigation District in the years 1915 and 1916. The rainfall during the months May to September, inclusive, in those years was 13.59 and 18.27 inches respectively.

Table No. 1 is the complete record of precipitation observed at Lethbridge from January, 1902, to December 28, 1919, showing an average annual rainfall of 15.613 inches.

## TABLE NO. 1.

### PRECIPITATION RECORD AT LETHBRIDGE, 1902-19, IN INCHES

| Month | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 | Average for 18 Years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.67 | 0.62 | 0.50 | 1.45 | 0.22 | 1.52 | 0.27 | 0.40 | 0.24 | 0.70 | 0.69 | 0.80 | 1.55 | 0.50 | 1.09 | 0.73 | 0.46 | 0.06 | 0.697 |
| February | 1.03 | 0.79 | 0.90 | 0.05 | 0.20 | 0.30 | 0.75 | 0.28 | 0.83 | 0.52 | 0.40 | 0.30 | 0.96 | 0.94 | 0.86 | 0.27 | 0.76 | 0.95 | 0.615 |
| March | 0.48 | 0.89 | 1.03 | 0.74 | 0.54 | 0.34 | 1.10 | 0.37 | 0.17 | 0.32 | 0.44 | 0.42 | 1.12 | 0.22 | 0.90 | 0.10 | 0.66 | 0.75 | 0.594 |
| April | 0.15 | 0.33 | 0.41 | 0.56 | 1.30 | 1.08 | 0.67 | 1.51 | 0.28 | 0.82 | 0.20 | 0.52 | 0.54 | 0.04 | 0.46 | 1.57 | 0.13 | 0.47 | 0.613 |
| May | 11.27 | 2.95 | 2.68 | 1.13 | 8.60 | 1.14 | 2.78 | 4.27 | 0.79 | 1.90 | 0.66 | 1.70 | 0.29 | 3.03 | 3.77 | 0.95 | 0.58 | 1.75 | 2.801 |
| June | 5.68 | 1.12 | 1.80 | 2.68 | 2.31 | 3.64 | 7.64 | 0.62 | 0.53 | 4.71 | 1.73 | 4.70 | 2.48 | 4.84 | 3.54 | 1.42 | 0.75 | 0.56 | 2.819 |
| July | 5.95 | 1.86 | 0.96 | 1.44 | 0.83 | 1.43 | 0.41 | 1.98 | 0.09 | 2.27 | 2.78 | 1.29 | 0.93 | 3.44 | 3.33 | 1.37 | 0.85 | 1.06 | 1.792 |
| August | 0.69 | 3.21 | 1.19 | 1.99 | 4.70 | 2.30 | 0.89 | 0.21 | 1.07 | 3.63 | 1.41 | 1.93 | 3.59 | 0.96 | 2.97 | 2.00 | 1.23 | 1.05 | 1.944 |
| September | 0.84 | 1.60 | 0.52 | 0.80 | 0.16 | 3.24 | 0.73 | 0.49 | 2.01 | 4.16 | 2.61 | 1.65 | 1.07 | 1.32 | 4.66 | 1.67 | 1.07 | 2.04 | 1.702 |
| October | 0.02 | 0.18 | 0.85 | 1.13 | 1.93 | 0.05 | 1.16 | 0.40 | 0.59 | 0.57 | 1.07 | 0.50 | 2.17 | 0.96 | 1.99 | 0.72 | 0.24 | 1.78 | 0.904 |
| November | 0.43 | 0.58 | 0.03 | 1.36 | 0.81 | 0.14 | 0.02 | 0.53 | 0.41 | 0.95 | 0.99 | 0.36 | 0.63 | 0.75 | 0.49 | 0.00 | 0.43 | 1.26 | 0.565 |
| December | 0.84 | 0.70 | 0.35 | 0.25 | 0.88 | 0.32 | 0.35 | 0.54 | 0.94 | 0.77 | 0.23 | 0.00 | 1.19 | 0.27 | 0.51 | 1.13 | 0.46 | 0.49 | 0.567* |
|  | 28.05 | 14.83 | 11.40 | 13.58 | 22.48 | 15.50 | 16.77 | 11.69 | 7.95 | 21.32 | 13.21 | 14.17 | 16.52 | 17.27 | 24.57 | 11.93 | 7.62 | 12.22 | 15.613 |

* For 28 days only.

The monthly rainfall, *during the cropping season,* in the years of less than normal precipitation, is shown in the following:—

**TABLE NO. 2**

**Rainfall during the cropping season**

| | 1904<br>in. | 1905<br>in. | 1909<br>in. | 1910<br>in. | 1917<br>in. | 1918<br>in. | 1919<br>in. |
|---|---|---|---|---|---|---|---|
| **May** | 2.86 | 1.13 | 4.27 | 0.79 | 0.95 | 0.58 | 1.75 |
| **June** | 1.80 | 2.68 | 0.62 | 0.53 | 1.42 | 0.75 | 0.56 |
| **July** | 0.96 | 1.44 | 1.98 | 0.09 | 1.37 | 0.85 | 1.06 |
| **August** | 1.19 | 1.99 | 0.21 | 1.07 | 1.37 | 1.23 | 1.05 |
| **September** | 0.52 | 0.80 | 0.49 | 2.01 | 0.72 | 1.07 | 2.04 |
| **Total** | 7.33 | 8.04 | 7.57 | 4.49 | 5.83 | 4.48 | 6.46 |

The irrigation allowance of 18 inches, applied to the land during the cropping season, is equivalent to an artificial rainfall practically as great as that of 1916, when there was 18.27 inches rainfall from May to September, inclusive (see Table No. 1 and remarks on page 6.) That would be the case, even if no rainfall occurred during these months, and the effect of the addition of irrigation allowance and rainfall will be apparent in the following notes.

The distribution of the net irrigation allowance of 18 inches in depth, during the same season, has been shown, in periods, on page 6 preceding.

First period, 41 days (from May 1 to June 10) gives a total of 4.4 inches, or 0.1073 inch per day. For May, 31 days, there would be 3.32 inches.

Second period, 35 days (June 10 to July 15) gives a total of 7 inches, 0.2 per day. For 20 days in June, 4.00 inches, giving June total of 5.08 inches and leaving 3.00 inches for the first 15 days in July.

Third period, 36 days (July 15 to August 20) gives a total of 4.4 inches, 0.122 inches per day. For 16 days in July 1.95 inches, giving July total of 4.95 inches, and leaving 2.45 inches for the first 20 days in August.

Fourth period, 41 days (August 20 to September 30) gives a total of 2.2 inches, or 0.537 inches per day. For 11 days in August, 0.59 inches, giving August total of 3.04 inches, and leaving for all of September, a total of 1.61 inches.

In summary:—

| | Ins. |
|---|---|
| **May** | 3.32 |
| **June** | 5.08 |
| **July** | 4.95 |
| **August** | 3.04 |
| **September** | 1.61 |
| **Total** | 18.00 |

Adding these amounts of irrigation allowance to the rainfall as shown on Table No. 2, as, in 1904:—

## TABLE No. 3.

| Months | Rainfall | Irrigation | Total water supply |
|---|---|---|---|
| | in. | in. | in. |
| May | 2.86 | 3.32 | 6.18 |
| June | 1.80 | 5.08 | 6.88 |
| July | 0.96 | 4.95 | 5.91 |
| August | 1.19 | 3.04 | 4.23 |
| September | 0.52 | 1.61 | 2.13 |
| Totals | 7.33 | 18.00 | 25.33 |

there would be a total water supply as shown in the following Table No. 4, to which has been added, for comparison, the monthly rainfall, during the cropping season, in 1916, when a bumper crop was secured on "dry" land.

## TABLE NO. 4

| Months | Rainfall plus Irrigation Allowance | | | | | | | Rainfall only |
|---|---|---|---|---|---|---|---|---|
| | 1904 in. | 1.05 in. | 1909 in. | 1910 in. | 1917 in. | 1918 in. | 1919 in. | 1916 in. |
| May | 6.18 | 4.45 | 7.59 | 4.11 | 4.27 | 3.90 | 5.07 | 3.77 |
| June | 6.88 | 7.76 | 5.70 | 5.61 | 6.50 | 5.83 | 5.64 | 3.54 |
| July | 5.91 | 6.39 | 6.93 | 5.04 | 6.32 | 5.80 | 6.01 | 3.33 |
| August | 4.23 | 5.03 | 3.25 | 4.11 | 4.41 | 4.27 | 4.09 | 2.97 |
| September | 2.13 | 2.41 | 2.10 | 3.62 | 2.33 | 2.68 | 3.65 | 4.66 |
| Totals | 25.33 | 26.04 | 25.57 | 22.49 | 23.83 | 22.48 | 24.46 | 18.27 |

(See also Appendix)

This shows, that in all these years of minimum precipitation, the addition of the irrigation allowance gives a total water supply, during the cropping season, in excess of that of 1916. And the monthly totals are greater throughout except in September. In the first three months in some of those years, the total water supply would be more than twice that of 1916, which might suggest an over supply. That could, of course, be avoided, by the application of a reduced irrigation supply, and that is entirely in the regulation of the water user.

It is not suggested that the large yields in 1916 were secured from that season's rainfall alone; the soil condition would, naturally, be affected by the rainfall of preceding periods. Thus, 1915 had a fair precipitation, while early snows in the fall of 1914, possibly long retained, may also have had a contributing, long-retained effect.

It will be plain, however, that the addition of the irrigation allowance provided for will place the equivalent of rainfall upon a better basis, if only because it would be a regulated and controlled basis, than the best that natural conditions have afforded, when abundant crops were secured; as in 1915 and 1916, when, according to the reports of the Dominion Experimental Station at Lethbridge, there was a yield of 63 and 48 bushels per acre, under dry farming conditions.

Adding the quantities required for irrigation supply to the canal losses sustained in transport, the canals should be capable of carrying, and the sources of water supply capable of furnishing, the following quantities of water in the various periods:—

| | |
|---|---|
| May 1 to June 10 | 585 second feet |
| June 10 to July 15 | 1089 second feet |
| July 15 to August 20 | 666 second feet |
| August 20 to September 30 | 292 second feet |

(See Table No. 6 Page 12 for details.)

Referring, for a moment, to the allowance of 34 per cent. for canal losses in transportation, it is the opinion that that is a full allowance under all the conditions. This important feature has been very carefully studied (see page 62 with table, Report on Irrigation Surveys and Inspections 1915, Department of the Interior, Canada, Irrigation Branch) and the conclusions are conservative, corresponding, generally, to actual results observed on several irrigation projects of the U. S. Reclamation Service, as quoted on page 62, and as given below:—

| | Percentage of Losses in Canals & Laterals |
|---|---|
| Umatilla | 32 |
| Truckee-Carson | 41 |
| Orland | 23 |
| Klamath | 48 |
| Tieton | 24 |
| Sunnyside | 27 |
| Average loss | 33 |

Such general comparison can be no more than indicative, of course, without consideration of all the related facts, and more reliance is placed upon the thorough study of the local conditions, supported as that is by the confirmation of results elsewhere.

The maximum canal capacity required, 1089 second feet, has been provided, as it has been already stated that the capacity from the siphon crossing of the Oldman River is 1098 second feet, while at the Kenex flume, nearly 42 miles below, it is 1017 second feet.

Studying the recorded stream discharge of the Oldman River in relation to the seasonal irrigation requirements, there is the following Table No. 5.

### TABLE NO. 5

Mean monthly discharge of Oldman River in cubic feet per second.

| Years | April Sec. ft. | May Sec. ft. | June Sec. ft. | July Sec. ft. | Aug. Sec. ft. | Sept. Sec. ft. |
|---|---|---|---|---|---|---|
| 1910 | .... | .... | .... | 756* | 461 | 624 |
| 1911 | 1779 | 5921 | 8357 | 1971 | 2080 | 4060 |
| 1912 | 1636 | 3148 | 3815 | 2999 | 1214 | 732 |
| 1913 | 2610 | 5220 | 6151 | 1811 | 1158 | 765 |
| 1914 | 1573 | 4102 | 3655 | 1511 | 768 | 674 |
| 1915 | 1713 | 6538 | 6155 | 3311 | 1645 | 948 |
| 1916 | 1595 | 3685 | 11510 | 5229 | 1597 | 1369 |
| 1917 | 853 | 6069 | 8706 | 2822 | 873 | 531 |
| 1918 | 1167 | 3037 | 4467 | 1147 | 668 | 551 |
| 1919 | 1253 | 4035 | 2716 | 892 | 461 | 310 |
| Average | 1575 | 4639 | 6170 | 2410 | 1092 | 1056 |
| Maximum Irrigation Needs | 0 | 585† | ( 585)†<br>(1089) | (1089)†<br>( 666) | (666)†<br>(292) | 292 |

* Records available from July 16 to 31 only.
† See top of page for periods.

It is immediately apparent, of course, that the *average* stream discharge is fully adequate for the maximum irrigation requirements and that the discharge to the end of June, *in any year*, is also ample.

In July, however, the mean monthly discharge is inadequate for the irrigation requirements during the first half of the month in two years, 1910 and 1919, and closely approximates it in another year, 1918.

That general condition exists in August, in the same years.

In September, the mean monthly discharge in 1919, 310 second feet, again closely approximates the irrigation requirement of 292 second feet.

The irrigation requirements considered are on the basis of 100 per cent. duty to the entire irrigable area. The project, as outlined, contemplates an 80 per cent. factor, as has already been stated, and, on that basis, the stream discharge would, even in August 1919, supply the needs, with a slight margin in excess. And the water right that supplies not less than 80 per cent. of the full requirement in a period of ten years would be considered a first class right.

Two features are to be considered in this particular project, however, *first*, that the ten-year record of stream discharge, complete as it is, may not cover a sufficiently long period to reveal the actual minimum flow; and *second*, that such a season of extreme minimum flow, as in the latter half of July and all of August and September of 1919, might occur at the commencement of the irrigation of the district.

It is unlikely that all of the irrigable area would be under cultivation and making demand for water supply in the first year of the operation of the irrigation system, or for some time after that, though the fact the area is now settled upon, and has been extensively cultivated previously, will create a heavier early demand for such water supply than is ordinarily the case in similar irrigation enterprises.

On the other hand, the canal system cannot be tuned up to full capacity immediately on the completion of construction. Any natural assistance that can be rendered to the usual operation should, consequently, be promptly availed of.

These considerations suggest the advisability of developing an available reservoir, at Keho Lake, at the inception of the enterprise, and there are other reasons for such suggestion.

It will be noticed that only during the second period of the irrigation season, from June 10 to July 15, or 35 days, is the designed maximum canal capacity of 1098 second feet, on the upper section, fully called upon, to the extent of 1089 second feet (see Table 5, page 10.) In the remainder of the season, the maximum capacity is drawn upon only from 60 to 26 per cent.

That may imply the possibility of reduction of canal capacity, with decreased cost, a desirable attainment in the initial stages of the enterprise.

Keho Lake is situated about 54 miles, by canal line, from the intake; and from it 84,255 acres, or 86.4 per cent of the entire irrigable area, can be served. Its capacity of 41,000 acre feet, less evaporation loss, would supply about 23 per cent. of the total irrigation requirements of the irrigable area below it, with canal losses added, and about 28 per cent. on 80 per cent. irrigation factor, if, for any reason, no water supply was available from any other source. If any accident should occur to the main canal above it, for 42 miles of which, to Kenex flume, there is, under the present scheme of the project, no irrigable area making demand for water supply, the reservoir capacity would maintain a supply to 86.4 per cent. of the irrigable area with practically total irrigation requirements including canal losses, in any one of the irrigation periods, except the second period, from June 10 to July 15, when it would supply 60 per cent. of the total requirement.

The reservoir covers a large surface area, about 3,690 acres at high water mark, and it is comparatively shallow, and would consequently sustain relatively heavy loss from evaporation and absorption. With that defect duly allowed for, however, in the foregoing remarks, its capacity of 41,000 acre feet is a distinct asset as an adjunct to the canal system. From its location, in relation to canal length and the greater extent of the irrigable area, it has the effect of bringing the Oldman River from the canal intake and placing it in the immediate vicinity of the lands to be irrigated.

Its advantage may be earliest and best realized, however, in reducing the necessary maximum capacity of the long reach of 42 miles of main canal at the initial stages of the enterprise. In such combination, the reservoir should be operated as part of the canal system and not wholly as a reserve supply, as is ordinary practice with storage reservoirs.

It would then be possible to reduce the maximum canal capacity, from the intake to Kenex flume, practically 42 miles, from 1,098 second feet maximum, reducing to 1,017 second feet, to 800 second feet throughout.

In order to appreciate the full result of the combination, the following schedule is submitted as the operation in a year of average stream discharge, with the entire irrigable area making 100 per cent. demand in each irrigation period and full canal losses added.

TABLE NO. 6.*

Schedule of operation of canal of 800 second feet capacity at Keho Reservoir of 41,000 acre feet capacity.

First period, May 1 to June 10.

4.4 inches needed - - - = .367 feet in 41 days
97531 acres by .367 - - = 35793.88 acre feet
add canal loss 34% - - = 12169.91 acre feet

Total requirement - - = 47963.79 acre feet
= 1169.85 acre feet per day
= 584.92 second feet per day

Capacity 800 second feet in 41 days would furnish - - 65600.00 acre feet

Leaving - - - - 17636.21 acre feet available for storage in the reservoir.

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* See Appendix for additional notes.

**Second period, June 10 to July 15.**

**7.0 inches needed - - - = .583 feet in 35 days**
**97531 acres by .583 - - - = 56861.57 acre feet**
**add canal loss, 34% - - = 19332.93 acre feet**

**Total requirement - - = 76194.50 acre feet**
**= 2177 acre feet per day**
**= 1088.5 second ft. per day**

**Canal capacity 800 second feet in 35 days would furnish - 56000.00 acre feet**

**Leaving - - - - - 20194.50 acre feet to be drawn from the reservoir.**

**Third period, July 15 to August 20.**

**4.4 inches required - - - = .367 feet in 36 days.**
**97531 acres by .367 - - = 35793.88 acre feet**
**add canal loss, 34% - - = 12169.91 acre feet**

**Total requirement - - = 47963.79 acre feet**
**= 1332.33 acre feet per day**
**= 666.16 second ft. per day**

**Canal capacity 800 second feet in 36 days would furnish - 9636.21 acre feet available for storage.**

**Fourth period, August 20 to September 30.**

**2.2 inches required - - = .183 feet in 41 days.**
**97531 acres by .183 - - - = 17896.94 acre feet**
**= 6084.95 acre feet**

**Total requirement - - = 23981.89 acre feet**
**= 584.93 acre feet per day**
**= 292.46 second ft. per day**

**Canal capacity 800 second feet in 41 days would furnish - 65600.00 acre feet**

**Leaving - - - - - 41618.11 acre feet available for storage.**

**(See tabulation of Canal Capacities, in periods, page 10.)**

It has been shown previously, however, that the minimum stream discharge, in some years, is inadequate to supply the irrigation requirement in the second period from July 15 to August 20 and closely approximates the requirements in the third period.

Applying the minimum stream discharge during these periods, the said test, there would be the following results:—

## TABLE NO. 7.

**Alternative based on minimum Stream discharge.**

**Third period, July 15 to August 20.**

**4.4 inches required - - - = .367 feet in 36 days.**
**97531 acres by .367 - - = 35793.88 acre feet**
**add canal loss, 34% - - = 12169.91 acre feet**

**Total requirement - - = 47963.79 acre feet**
**= 1332.33 acre feet per day**
**= 666.16 second ft. per day**

**Stream discharge in 1919, 584 second feet in 36 days, would furnish - - - - - = 42048.00 acre feet**

**Leaving - - - - - - = 5915.79 acre feet to be drawn from storage.**

**Fourth period, August 20 to September 30.**

**2.2 inches required - - - = .183 feet in 41 days.**
**97531 acres by .183 - - - = 17896.94 acre feet**
**add canal loss, 34% - - - = 6084.95 acre feet**

**Total requirement - - - = 23981.89 acre feet**
**= 584.93 acre ft. per day**
**= 292.46 second ft. per day**

**Stream discharge in 1919, 320.6 second feet, in 41 days, would furnish - - - - 26289.20 acre feet**

**Leaving - - - - - 2307.31 acre feet available for storage.**

In years of average stream discharge, the reservoir would be filled at the end of September, from the canal and reservoir operation of the season, as has been shown in the first section of the foregoing tabulation, when 41,618 acre feet, more than its total capacity, is shown to be available for storage in the fourth period, August 20 to September 30.

Any loss from evaporation and absorption, during the months intervening to the opening of the next irrigation season, would be replaced before May 1, certainly before June 10. The canal could, ordinarily, be in operation before May 1, when all the water carried by it could be delivered to the reservoir. And the schedule shows that, in the first period, May 1 to June 10, 17,636 acre feet would be available for storage over and above irrigation requirements, and that quantity is certainly more than the reservoir losses in seven months would amount to.

And, equally of course, the withdrawal of 20,194.50 second feet, during the second period, and all losses in that period, would be replaced during the third and fourth periods, when 51,254.32 acre feet are shown to be available for storage.

In years of average stream discharge, then, a canal of 800 second feet maximum capacity in combination with Keho Reservoir, would supply the total irrigation needs of the entire district, on 100 per cent. irrigation factor, with the reservoir full at the beginning and the end of the season, and the operating schedule would be as follows:—

TABLE NO. 8.

| | In storage beginning of period acre feet | Available for storage acre feet | In storage end of period acre feet | Waste acre feet |
|---|---|---|---|---|
| May 1st | 41,000 | ----- | ----- | ----- |
| May 1st to June 10th Available | 41,000 | 17,636 | 41,000 | 17,636 |
| June 10th to July 15th Draw | 41,000 | —20,194 | 20,806 | ----- |
| July 15th to Aug. 20th Available | 20,806 | 9,636 | 30,442 | ----- |
| Aug. 20th to Sept. 30th Available | 30,442 | 41,618 | 41,000 | 31,060 |

**In years of minimum stream discharge, a canal of 800 second feet maximum capacity, in combination with Keho Reservoir, could supply the total irrigation needs of the entire district on 100 per cent. irrigation factor, with the reservoir full at the beginning, and 41.94 per cent. full at the end of the season, and the operation schedule would be as follows:—**

TABLE NO. 9.

| | In storage beginning period<br>acre feet | Available for storage<br>acre feet | In storage end of period<br>acre feet | Waste<br>acre feet |
|---|---|---|---|---|
| May 1st | 41,000 | ----- | ----- | - - -- |
| May 1st to June 10th<br>Available | 41,000 | 17,636 | 41,000 | 17,636 |
| June 10th to July 15th<br>Draw | 41,000 | —20,194 | 20,806 | -- --- |
| July 15th to Aug. 20th<br>Draw | 20,806 | — 5,916 | 14,890 | --- - |
| Aug. 20th to Sept. 30th<br>Available | 14,890 | 2,307 | 17,197 | ----- |

In the period of 71 days, June 10 to August 20, the evaporation loss would not exceed 6,000 acre feet. At the lowest the reservoir might not have to exceed 10,000 acre feet on storage at the end of the season.

To supply the deficiency of 31,000 acre feet, prior to the extreme irrigation requirements of the succeeding season, there would be available any water that would be transported through the canal during the month of October, and in the latter half, at least, of the following April.

The lowest recorded stream discharge during October is 395 second feet, in 1917, following a discharge of 531 second feet in September of that year. The discharge during September of 1919 was 302.6 second feet. If a minimum flow of 300 second feet during October is assured, there would be a total of 18,600 acre feet, less loss in transit, supplied to the reservoir.

It is probable that the canal would not be operated, ordinarily, prior to April 15. The minimum mean monthly discharge of the Oldman River during April is 853 second feet, more than the canal capacity considered in this connection, 800 second feet. The latter quantity would provide, in fifteen days, 24,000 acre feet.

October and April could thus be depended upon to supply 42,000 acre feet, gross, from which a canal loss, *from the intake to the Reservoir*, of 30 per cent., or 12,600 acre feet may be deducted, leaving 29,400 acre feet, against the required amount of 31,000 acre feet. And the tabulation, Table No. 6, has shown that during the first period, May 1 to June 10, 17,636 acre feet would be available for storage, altogether providing an ample volume to assure full supply in the reservoir before any draft is made upon it.

On the basis of an 80 per cent. irrigation factor, a canal capacity of 800 second feet, depending upon the minimum stream discharge, and *without* the reservoir, would supply all irrigation requirements, except during the second period, June 10 to July 15, when there would be a shortage of 4,956 acre feet, in these 35 days. That implies that, to give full service, the canal capacity should be enlarged by 71 second feet.

During the third period, the 800 second feet canal could deliver all of the irrigation requirements and have a surplus of 3,677 acre feet, less than 10 per cent. margin.

In the inevitable expansion of the irrigable area, the construction of Keho Reservoir would be essential.

With the addition of the Rocky Coulee and the Barons-Carmangay districts, in a total irrigable area of 31,940 acres, a canal of 800 second feet capacity and the reservoir would supply the irrigation requirements and canal losses, on the basis of an 80 per cent. irrigation factor. Upon 100 per cent. irrigation factor, the canal capacity would require enlargement, and upon the minimum stream discharge, probably another reservoir in addition to Keho Reservoir. And such additional reservoir would be necessary, in the event of any further additions to the District, other than Rocky Coulee and Barons Carmangay, as the Sundial and others, which are under consideration.

Upon the inclusion of the Rocky Coulee and the Barons-Carmangay districts, and any further expansion of the irrigable area eastward, the natural direct route of the main canal is north from Kenex flume and through Keho Reservoir, rather than by the detour round the south flank of the Black Springs Ridge.

The cost of the alternative propositions cannot be overlooked in any determination of their relative economic value.

To include Keho Reservoir on the initial construction involves the addition, in excavation, of the following:—

| | | Cubic yards. |
|---|---|---|
| Main canal— | | |
| From Kenex flume to Reservoir Inlet, 46,300 lin. ft. | | 416,700 |
| Reservoir Inlet, 16,000 lin. ft. | | 576,600 |
| Reservoir Outlet, 20,000 lin. ft. | | 418,000 |
| Branch canal— | | |
| Kenex flume to Reservoir outlets— | | |
| Kenex branch | 101,300 cub. yds. | |
| Return branch | 114,000 cub. yds. | |
| | | 215,300 |
| Total | | 1,626,600 |

The following reduction in excavation would be made:—

| | | |
|---|---|---|
| Main canal— | | |
| From siphon crossing Oldman River to Kenex flume | 405,000 cub. yds | |
| From Kenex flume to Reservoir outlet 127,900 lin. ft. | 1.419.190 cub. yd | |
| | | [illegible],190 |
| Reduction in excavation | | 197,590 |

In structures, there would be reduction in the capacity of the siphon crossing of the river, one railroad crossing on the present main canal, and additions of a more expensive railroad crossing over the inlet to the reservoir and the control gates at the reservoir. The sizes of the flumes on the main canal above the Keho Reservoir could be reduced but that saving may be disregarded for the present.

There would then be:—

| | | |
|---|---|---|
| **Reduction—** | | |
| 197,590 cub. yds. excavation at 35c per cub. yd. | | $ 69,156.50 |
| Railroad crossing | | 8,000.00 |
| Siphon crossing at the river | | 25,000.00 |
| | | $102,156.50 |
| **Addition—** | | |
| Railroad crossing over Inlet | $40,000 | |
| Control gates at Reservoir | 35,000 | |
| Balance | | $ [illegible] |
| To that has to be added the cost of the land included in the water surface area of the reservoir 3,690 acres, estimated at $15 per acre | | 5[illegible] |
| | | $ 2[illegible] |

Showing that the inclusion of the Reservoir would cost $28,193.50 more than the present design of the system.

Further reduction of the cost of the main canal would be expected in the final location of the line.

The value to the project of the inclusion of the reservoir is obviously very much greater than $28,193.50. In case of accident to the main canal above, at a critical period in the irrigation season a reserve supply of 41,000 acre feet, at the edge of the greater extent of the irrigable area, might produce results, in one season, many times the equivalent of the additional cost of construction.

It may be too early to express an opinion of the value of an acre foot of water, under this particular enterprise, but the addition of one and a half acre feet per acre, to the irrigable lands, will raise production from the average dry farming results of 30 bushels of wheat per acre to 53 bushels under irrigation. (See results reported by Dominion Experimental Station, Lethbridge). At the modest price of $1 per bushel, there is an increased production of $23 per acre, or roughly $15 per acre foot per annum. A very low capitalization of that annual productive value, per acre foot, would warrant an addition to the system that represents an added cost of less than 70 cents per acre foot, 41,000 acre feet at cost of $28,193.50.

The right to water from the Oldman River, in volume sufficient for the needs of the District, has been arranged by provisional filing made by the Department of the Interior, during the early stages of the work of survey.

## CHARACTER OF SOIL AND ADAPTABILITY TO IRRIGATION

From comprehensive inspection of the irrigable area, there is no room for doubt of the adaptability of the entire acreage included in the District, to farming under irrigation.

The soil varies, from clay loam to sandy loam, on the irrigable tract, with some gravel interspersed in the upper section. The latter would affect, for the present, the conditions of canal construction only, as none of the lands on the upper section are included in the irrigable area at this time. It is inevitable, in the writer's opinion, that sooner or later, these lands, particularly east of Willow Creek, which are, generally, out of the gravel belt, will seek a water supply and will prove equally adaptable to irrigation.

The land surface is throughout smooth and uniform, with sufficient surface inclination. Inspection of the area compels the conclusion that the engineers, in selection and classification of the lands to be included in the irrigable area, have been most careful and conservative, alike as to physical characteristics and soil conditions.

On the former, there appears to be considerable areas, especially in the Turin district, which have been excluded from the irrigable area, presumably on account of greater irregularity of surface slope and rolling or broken surface, involving increased cost in distribution laterals. These additional tracts will inevitably seek inclusion, even with the extra burden of cost directly upon the owner.

The investigations made of soil character have been of a most painstaking and searching character. General inspection reveals unusually slight indications of alkali, and subsequent inquiry indicates that even the slightest of these have been excluded, following upon comprehensive soil tests. In the Department's Report for 1916-17, page 24, reference is made to 108 such tests, all subjected first to "electrical bridge," and when indicating above moderately strong alkali, at any depth, the samples were sent to Ottawa for chemical analysis, and, upon such methodical examinations, the final limitations of the irrigable area were determined.

It may be doubted if the adaptability of the soil to irrigation conditions has ever been so completely investigated in any such undertaking, before construction began, or water was actually applied to the land.

Consideration has also been given to the conditions governing surface drainage.

Altogether, it is my conclusion that the total irrigable area of 97,531 acres is well adapted to irrigation, that the area is conservatively stated, and that an increase within the present limits may be expected within a reasonable time, if such increase should be desired.

There does not appear to be any necessity to comment upon the general climatic conditions as affecting agricultural pursuits in that district, that is well established. Crops can be grown whenever the *rainfall, or its equivalent, during the cropping season* is sufficient for the needs of the growing crop.

That phase has already been fully considered in the discussion of the addition of the irrigation supply to the normal rainfall, in the cropping season, during 1916, when bumper crops were produced.

## CANAL LOCATION AND STRUCTURAL FEATURES.

The district over which the canal system would be constructed presents, generally, very favourable conditions, alike for location and construction: it is rare, indeed, to find, in a project of this magnitude, so few obstacles involving any engineering problems. That may best be illustrated in the statement that, in the first 50 miles, practically to the Keho Reservoir, or, if the originally planned route is adopted, to the first irrigable area, there are, apart from the intake works, four structures other than earthwork, a siphon crossing at the river, 3,379 feet long, and three wooden flumes, one crossing Willow Creek, 2,900 feet long, the second, at Rocky Coulee, 3,000 feet long, and the third, near Kenex, 1,100 feet long, the two latter crossing a depression extending north-easterly throughout the entire distance between the Oldman and Little Bow Rivers.

The general uniformity of the ground surface permits a location with slight deviation from the general course, with the exception of a northerly trend for some distance after crossing to the north side of the river. And that same feature of surface uniformity will result in an economic location, for construction purposes, involving no serious amount of extra depth of cutting, except immediately east of Willow Creek, and in some extra "filling" near Rocky Coulee, where the depression just mentioned involves some care in location to secure the most direct route with the least expenditure.

The existing projected location reveals careful study of the topographic features and while it is to be expected that improvement will be made upon final field location, in terms of shortening distance and reducing total quantity of excavation, on which further comments will be made, the work which has been done—and so thoroughly well done—affords a sound foundation for estimation of quantities involved at this stage of the enterprise.

Test borings have been made along the route of the main canal, at intervals of two miles, for the purpose of ascertaining the character of the material to be encountered in excavation. These indicate the presence of gravel for two or three miles north of the river crossing, as well as in some parts of the section from the intake to the siphon crossing, approximately four miles. In these stretches, for some time after operation begins, there may be considerable seepage, involving mostly loss of water in that section of the canal. It is most probable that, with sufficient drainage and the continuance of the gravel stratum to the river, no surface damage to the intervening lands will be entailed. In the course of time, from natural or artificial operations, this section may silt, or it may become necessary to line this portion of the canal, and the required expenditure be really a maintenance charge.

In order to avoid "cut banks" on the north side of the river, involving prohibitive cost and difficult construction and maintenance, the intake works are located on the south bank of the river, about nine miles west of Macleod. The site for dam and intake are entirely suitable. While the information obtained from the test pits sunk near the intake, to ascertain the character of the underlying material, is not wholly conclusive, it is reasonable to assume that the dam will rest on a pervious foundation, and the designs have been made accordingly, adequate to the situation, and may be modified, as work progresses and extended information is secured.

There is no evidence of liability of the river, in extreme discharge, to "cut around" the structure, on the north side only, as, on the south side, the structure abuts on the natural wall of the valley. And, to fully provide against any such tendency, a levee, or embankment, will be carried out on the north side to the level of the north wall of the dam, which will be carried to such height as will provide passage for maximum discharge of the river. And, in such levee construction, all depressions that may suggest evidence of old channels will be filled in and fully protected.

Due regard has been paid to the volume of possible maximum flood of the river, provision being made for the passage of 40,000 second feet, representing 6.5 feet in depth over the crest of the dam, 650 feet long.

The design for the intake works, including dam, headgate, sluiceway, etc., has been carefully studied and is adequate for all the conditions. Modifications may be made with the view of reducing cost without reducing efficiency.

To pass from the south to the north side of the river, a siphon crossing has been designed at a location some four miles below the intake, where the topographic conditions are favourable. A structure, 3,379 feet long, with three spans of steel bridge 120 feet long each, over the river channel proper, will be built, which, for the present, and as included in the estimate of cost, will consist of one wooden stave pipe, 12 feet in diameter, carrying 1,118 second feet, with provision in the bridge proper, for another such pipe.

An alternative plan may be the construction of two pipes, 9 feet in diameter, only one of which will be built, at first. And there is the further alternative of reducing the capacity of the main canal, as indicated in the discussion of the inclusion of the Keho Reservoir, on original construction.

There is no occasion for extended comment on the remaining structural features. They are of standard wooden flume design adequate for the requirements, and are unavoidable.

The earthwork excavation will be of the usual character, marked only by the relative magnitude of the total quantity.

And these remarks apply equally to the location and structural designs for the branch canals and distributary laterals, covering the irrigable area itself. Ample provision has been made for spillways and for the protection of natural channels, when used either as part of the carrying canal systems or for the removal of excess water.

## ESTIMATE OF COST OF CONSTRUCTION.

In submitting an estimate of the cost of construction of the works involved in this enterprise, it is fitting to comment upon the extraordinary condition of the times as affecting all elements of construction. Never before has the task of estimating cost, with reasonable accuracy, imposed so much anxiety and responsibility upon engineer and contractor alike, a fact that is readily realized by those engaged, or seeking to engage, in large undertakings of the character under consideration. Under the prevailing circumstances, with no assurance that the prices ruling today will govern sixty days from now, but with the conviction that any change is likely to be upward for some considerable time in the future, such estimates must be high, and appear, perhaps, unduly high, to those by whom the burden is ultimately borne.

In addition to the conditions generally prevailing, there are elements affecting cost of irrigation development—and in this particular project under consideration, perhaps peculiarly—which must be steadily kept in mind. There is the remoteness from centres of contracting organizations, distance from railroad facilities, limited season in which work can be prosecuted, and a tendency, more in irrigation construction than in most other fields, for necessary work to increase in items and amounts.

In this particular case, while, as has been noted, a final field location has not been made, there are sufficient data on which to base an accurate judgment of the *quantities* of material involved. It is my opinion that the final location will result in many items of reduction, small in individual amount, perhaps, but considerable in total result. I have carefully gone over these quantities in the various classes of work and am confident that they are amply large, in all classifications, so much so that they afford latitude for much change, either in design or location.

On the details of unit prices, I have inquired into the prevailing conditions, though there has not been much of this class, or magnitude, of work in the vicinity for some years. I have thoroughly gone over the data affecting cost with Mr. H. B. Mucklestone, who, as Chief Engineer of the Lethbridge Northern Irrigation District, will be in charge of construction, and who, as Assistant Chief Engineer on the Canadian Pacific Irrigation works has had extended and recent experience in this class of construction.

In adopting, largely, the unit prices determined by him I am confident that they are ample, and while, in items apparently large, are, under analysis, just to the conditions of today.

And, in both quantities and prices, my conclusion is that they are ample to cover all the elements of the work, sufficient to provide for possible modification or alteration of plans, and are as low as can be employed at this stage without misleading those who shall determine the advisability of entering upon the project and those who must ultimately bear the burden.

## ESTIMATE OF COST

| | | |
|---|---|---|
| **Headworks:** | | |
| Excavation:— | | |
| 3,600 cub. yds., dry, at 40c per c. y. | $ 1,440 | |
| 9,700 cub. yds., wet, at $1.50 per c. y. | 14,550 | |
| Coffer dam | 19,268 | |
| Concrete:— | | |
| Plain, 4,153 cub. yds., at $12.75 per c. y. | 52,951 | |
| Reinforced, 480 cub. yds., at $27.37 per c. y. | 13,138 | |
| Control Gates, etc. | 10,000 | |
| Rip-rap, 8,000 cub. yds. (estd.) at $1.00 per c. y. | 8,000 | |
| | | $ 119,347 |
| **Excavation:** | | |
| First section | 362,651 cubic yards | |
| Main canal | 3,756,110 " " | |
| Branches | 582,939 " " | |
| Distributaries | 1,285,501 " " | |
| Total | 5,987,201 cubic yards | |
| Say 6,000,000 cubic yards at 35c per cubic yard | | 2,100,000 |
| **Siphon crossing of Oldman River,** 3,379 feet long. | | |
| Wood-stave pipe | $ 81,028 | |
| Steel bridge [illegible] span | 111,360 | |
| | | 192,388 |
| **Wooden flumes:** | | |
| **Willow Creek,** 2,900 feet long. | | |
| Timber, 944,000 ft. b. m. at $76.60 per M. | $72,310 | |
| Piling, 17,000 lin. ft. at 20c per ft. | 3,400 | |
| Piledriving, 11,000 lin. ft. at 70c per ft. | 7,700 | |
| | | 83,100 |
| **Rocky Coulee,** 3,000 feet long. | | |
| Timber, 1,104,000 ft. b. m. at $85.00 per M. | $93,840 | |
| Piling, 14,700 lin. ft. at 20c per ft. | 2,940 | |
| Piledriving, 10,000 lin. ft. at 70c per ft. | 7,000 | |
| | | 103,780 |
| **Kenex,** 1,100 feet long. | | |
| Timber, 420,000 ft. b. m. at $85.00 per M. | $35,700 | |
| Piling, 5,000 lin. ft. at 20c per ft. | 1,000 | |
| Piledriving, 4,000 lin. ft. at 70c per ft. | 2,800 | |
| | | 39,500 |
| Railway Bridge crossings, (2) Main Canal at $8,120 each | | 16,240 |
| Concrete Siphons at Railway Crossings (3) | | 12,320 |
| General Timber Construction, on Branch, Secondary and Distributary Canals, including lumber, framing, hauling, excavation, trenching, refilling, replacing, etc. | | |
| Total quantity, 2,600,000 ft. b. m. at $125 per M. b. m. | | 325,000 |
| Piling in connection with above | | 26,534 |
| General Concrete Construction, on Branch, Secondary and Distributary Canals, including all items. | | |
| 4,236 cub. yds. reinforced at $55 per c. y. | | 232,980 |
| Plain concrete, 54 cub. yds., at $15 per c. y. | | 810 |
| Corrugated Pipe Culverts, 41,160 lbs. at 9c. per lb., metal only | | 3,704 |
| Steel Flumes, 52,452 lbs. at 9c. per lb., metal only | | 4,720 |
| Fencing, 40 miles at $300 per mile | | 12,000 |
| Telephone line, 42 miles at $300 per mile | | 12,600 |
| Right-of-way, 2,400 acres at $40 per acre | | 96,000 |
| Buildings, for Ditch tenders | | 20,000 |
| Engineering, incidentals and contingencies | | 510,153 |
| On 97,531 acres, $40.12 per acre, total | | $3,911,176 |

Of the large item, in quantity and total cost, earthwork excavation, it may be repeated that, on final location of the canal line, reduction may be reasonably expected. And that may not only be represented by distance and quantity, but in unit price. The greater portion of the main canal should be excavated by machinery, drag line scraper, and the location of the canal, in respect to depth of cutting, should be governed with such work in view, avoiding any undue amount of overhaul, desirable and economical if the greater portion of the work was to be performed by teams and scrapers. Some overhaul is unavoidable, of course, as in the vicinity of Rocky Coulee and the general "depression" previously referred to.

With the large quantity of timber work, especially in the Branch and Subsidiary Canals, at considerable distance from railroad points, extra hauling is involved, and with the multiplicity of structures, much excavation and trenching, all contributing to increased cost, and that also applies to concrete construction in that part of the district.

The extent of fencing has been reduced. While fencing a canal line is generally desirable, though accompanied by some disadvantages that increase cost of operation, there are some local conditions surrounding this enterprise that suggest the careful selection of the stretches to be fenced. It is plainly evident that drifting soil and weeds create an unusual condition to be specially reckoned with, and the erection of fences especially along the canal where there is limited cultivated area, or none at all, in the immediate vicinity, may fail to afford the canal the protection desired, but may actually increase the cost of operation, by creating drifts from which accumulation in the canal adjoining may be greatly enlarged.

The telephone line is provided on main roads along the main canal only.

The buildings, for which the sum of $20,000 has been included, are only such as will be required at the intake and at division points along the canal for the ditch-riders and do not include offices, etc., which the District may require, but which, for the present, it is assumed would be included in operation expenses, under rentals.

Under all the existing circumstances, it is considered that an addition of 15 per cent. to cover engineering expenses, incidentals and contingencies is the least that should be made. Much engineering work has been done that will be very helpful to the future prosecution of the work, but much more has to be done that may appear as duplication, as, for instance, the final permanent location of canal routes. The District has incurred some expense which should be covered in this item of contingencies.

The foregoing estimate is based upon the canal location and plans as now designed, that is, omitting Keho Reservoir, and on the maximum carrying capacity of 1098 second feet below the siphon crossing of the Oldman River, and no credit is given for any reduction that may be made possible by the alternative route.

## ESTIMATE OF COST AND MAINTENANCE AND OPERATION

Before taking consideration of the financial requirements for the cost of construction, the cost of maintenance and operation may be forecast, as that feature, in a measure, may be involved in the financial provisions.

### MAINTENANCE.

Under maintenance, there would be the items of general overhead expenses, sinking fund for renewal of perishable structures, and provision for accidental damage.

For the first, a general allowance of one-half of one per cent. on the total construction cost would prove sufficient—or $19,556.

For renewals, there are the three wooden flumes mentioned, with a total estimated cost of $226,380. These, with good construction, should have a life of twenty years.

For the larger quantity of smaller wooden structures, throughout the branch system, involving a total expenditure of $325,000, it would be conservative to estimate upon the shorter life of ten years.

The wood-stave pipe, $81,028, should last fifteen years, a very low estimate in my own observation of such construction.

Of the reinforced concrete construction, siphons, etc., in the eastern section of the system, $50,000 may be counted upon for renewal within nine years.

Fencing and telephone line will require renewal within eight years and may be reckoned on the basis of direct allowance.

Maintenance requirements would thus become—

| | | | | |
|---|---|---|---|---|
| Overhead provision | | | | $19,556 |
| | **Sinking Fund** | | | |
| Flumes | $226,380 | — 20 years — | $ 6,846 | |
| General Timber | 325,000 | — 10 years — | 25,837 | |
| Siphon | 81,000 | — 15 years — | 3,754 | |
| Concrete Siphons | 50,000 | — 9 years — | 4,545 | |
| Fencing | 12,000 | — 8 years - | 1,250 | |
| Telephone line | 12,600 | — 8 years — | 1,312 | |
| | | | | 43,544 |
| Accidental damage | | | | 1,000 |
| Total | | | | $64,100 |

### OPERATION.

Under operation, there would be, in the general organization, engineering superintendence, including superintendent, at $4,800 per annum, two assistant superintendents at $2,400 each per annum, one draftsman, at $1,50[illegible]cond at $1,000, and stenographer at $1,200, a total of $13,300.

In charge of the distribution and service of water, one water master may care for 8,000 acres, requiring 12 water-masters at $1,800 per annum each, a total for this item of $21,600.

In patrol, the main canal would be divided into four sections: *first,* from the intake to the siphon crossing; *second,* from siphon crossing to Rocky Coulee flume; *third,* from Rocky Coulee flume to Keho Reservoir; and *fourth,* the Keho Reservoir and outlet canal, or the two last mentioned divisions would be offset by similar sections on the main canal, if Keho Reservoir were not included. These patrol-men would receive $1,500 per annum each, a total of $6,000.

An expensive item in canal operation would consist of cutting weeds, at least on the right-of-way owned by the District. That area has been included in the estimate of cost at 2,400 acres. A burden of probably $12 per acre per annum may be entailed in this necessary work, or $28,000; say $30,000 in all.

For general up-keep of the main canal, in the removal of sand, silt, etc., it may be estimated that, out of the total length, 30 miles may involve an annual expenditure of $300 per mile, or $9,000; say $10,000 per annum. This burden will be affected by the careful location of fencing, as has been mentioned in connection with the cost of construction, and some part of it may be reduced by judicious expenditure on *forestry,* along the canal line. An annual expense of $2,000 in such work may materially reduce the annual cost of cleaning, but, as some time would elapse before its beneficial effect would be felt, the allow[illegible]0,000 should be reckoned upon.

Some up-keep of buildings, structures, etc., in renewal by painting, etc., will be incurred, for which an annual provision of $1,000 should be allowed, and another provisional fund of $1,000, annually, should be made for wilful damages that may occur.

For necessary equipment, to care for service of the organization, in plant and animals, $5,000 per annum should be provided.

For the head office, it has previously been stated that, at first, quarters should be rented, in place of buildings erected, and such rental would be covered by $900 annually, and—with a secretary, at $2,400 per annum, stenographer at $900, printing, stationery, etc., $500, incidentals, $300—would give an annual total of $5,000.

A telephone exchange will become a necessity, at a probable expense of $1,800 per annum.

The compensation and expense of the Board of Trustees (3) may amount to $5,000 per annum, and legal expenses involve the annual expenditure of $6,000.

It may be anticipating the growth of the system to make any provision for superannuation at this time, but such will become an item that must be considered, and an allowance of $2,000 should be included now for that purpose.

Summarizing, there would be—

| | |
|---|---|
| **Engineering Superintendence** | $ 13,300 |
| **Water-masters** | 21,600 |
| **Patrol** | 6,000 |
| **Cutting weeds** | 30,000 |
| **Removal of sand, silt, etc.** | 10,000 |
| **Up-keep of structures, painting, etc.** | 1,000 |
| **Damages** | 1,000 |
| **Equipment** | 5,000 |
| **Head Office, Organization** | 5,000 |
| **Telephone Exchange** | 1,800 |
| **Board of Trustees** | 5,000 |
| **Legal Expenses** | 6,000 |
| **Superannuation** | 2,000 |
| **Total** | $107,700 |

Combining maintenance and operation expenses, there is a total of $171,800, which, on 97,531 acres, means $1.76 per acre per annum.

In 1912, the summary of operation and maintenance results under 26 irrigation projects of the U. S. Reclamation Service, gives these combined costs at $1.26 per acre. Without knowledge of all the related facts, this comparison may be interesting rather than confirmative of the accuracy of the estimate here made, which is, by itself, submitted as full and conservative. It should be added that the total cost in the U. S. Reclamation Service review includes large and small projects. In a number of cases, the cost of necessary drainage is embraced, and in all, the total expense is applied to all the irrigable area though the area actually irrigable is much less than that, and there are only three projects in which the total irrigable area is greater than that of the Lethbridge Northern Irrigation District.

## FINANCIAL PROVISIONS

While the sum of $3,911,176 is amply sufficient to construct the complete canal system to irrigate 97,531 acres, at the rate of $40.12 per acre, irrigable, additional financial provision must be made to place the District on the basis of a going concern.

Interest during construction on the requisite funds as they are needed, and discount on bond issue must plainly be provided for. In addition to that, however, it will be wise to arrange for the interest payment for, at least, one year after canal completion, in order to give the farmer an opportunity to "find himself"; and one year's cost of maintenance and operation should be added to that, if possible, while the organization should have a working capital to start with.

Two years, or rather two working seasons, will be required to complete the construction. Under extremely favourable circumstances, with the work in the hands of a thoroughly equipped organization with previous experience in the particular character of work, it might be possible to complete it in one year, though the seasonal limitation is a serious handicap. Two seasons should form the basis of calculation, at least, and it may be pointed out that beginning with March, 1920, for instance, two seasons would extend to May, 1922, the month when the canal would first be in operation for the year.

It will be assumed that bonds are issued to the amount of $5,000,000, to be delivered as required—at 6 per cent. interest—30 years, that there would be discount of 5 per cent., that, during the first season, $1,750,000 would be expended on the works, and the balance in the second season.

The final schedule would then be—

| | | | | |
|---|---|---|---|---|
| **1920** | Total amount | | | $5,000,000 |
| | Capital drawn | | $2,000,000 | |
| | Less discount | | 100,000 | |
| | | | | $1,900,000 |
| | Expended on construction | | $1,750,000 | |
| | Interest on $2,000,000 | | 120,000 | |
| | | | | $1,870,000 |
| | Balance | | | $ 30,000 |
| **1921** | Balance on hand | | | $30,000 |
| | Capital drawn | | $2,500,000 | |
| | Less discount | | 125,000 | |
| | | | | 2,375,000 |
| | | | | $2,405,000 |
| | Expended on construction | | $2,161,175 | |
| | Interest on $2,000,000 | | 120,000 | |
| | Interest on $2,500,000 | | 90,000 | |
| | | | | $2,371,176 |
| | Balance | | | $ 33,824 |
| **1922** | Balance | | | 33,824 |
| | Balance of capital drawn | $500,000 | | |
| | Less discount | 25,000 | | |
| | | | $475,000 | |
| | Year's interest on total issue | $300,000 | | |
| | Year's maintenance and operation | 171,800 | | |
| | | | $471,800 | |
| | | | | 3,200 |
| | Working capital remaining | | | $37 024 |

$5,000,000 on 97,531 acres means $51.26 per acre.

In the event that the estimates of cost submitted are found to be high, there would be open the alternative courses of either not realizing on all of the bond issue or of conserving the surplus to longer extended credit to the farmer on interest payments and maintenance charges, a policy which should not be carried too far, however. Under all the existing conditions, it would neither be wise nor prudent to initiate the undertaking on a smaller financial provision than outlined. Any alteration in the final results will involve, it is true, an adjustment of the assessment of burdens against the land, but that, wholly a matter of accounting, can be cared for without serious inconvenience, either to the administration or to the landowner.

A sinking fund for final repayment of the bond issue must be provided. It is suggested that its creation may be deferred for ten years, and the accumulation made in the last twenty years of the life of the bonds. On a 5 per cent. basis that means an annual contribution of $151,200, for a period of twenty years, or an addition of $1.55 per acre to the charges for interest, and maintenance and operation. Deferring for ten years, the start to an accumulating fund, may seem unduly postponing a prudent action. In that time, however, the security for the bonds will have materially enhanced in value and the landowner will have gained in experience, to an extent that will represent a steadily increased production, in amount and value, and will thus be better able to carry the slightly increased burden.

The prosecution of the enterprise involves to the land owner—

(*a*) The interest on bond issue amounting to $3.07 per acre per annum.

(*b*) The maintenance and operation cost amounting to $1.76 per acre per annum and after 10 years from the issuance of the bonds.

(*c*) The contribution to sinking fund amounting to $1.55 per acre per annum.

In the narrowest conception of the proposition, the strictly commercial view, the test of its soundness is in the question: Can the landowner, by the addition of $4.83, say $5 per acre per annum, to ordinary farming expenses, during the first ten years, secure such increased production as will, in normal times and at normal prices, justify that additional burden? In another form the question becomes: Will farming by irrigation warrant the addition of $51.26 per acre to the land and will the additional returns yield adequate interest upon that increased value?

In addition to the overhead costs of $4.83, or $5 per acre, referred to, there would be the cost of ditching and irrigation, which would be fully covered by an addition of $1 per acre, making in all $6.00 per acre of added expense, in the first period of ten years, to ordinary "dry" farming methods.

A tabulation of "Comparative Results in Crops grown on Dry Land and Irrigated Land, at the Experimental Station, Southern Alberta," by Mr. W. H. Fairfield, Superintendent, gives valuable information on the relative production secured under what may be termed the natural and the artificial conditions.

The following shows the comparison in wheat-growing—

| | Dry bushels | Irrigated bushels | Per cent Increase |
|---|---|---|---|
| 1908 | 29 | 43 | 48 |
| 1909 | 31 | 40 | 29 |
| 1910 | 11 | 23 | 109 |
| 1911 | (Hailed) | -- | -- |
| 1912 | 28 | 50 | 78 |
| 1913 | 25 | 52 | 108 |
| 1914 | 24 | 54 | 125 |
| 1915 | 63 | 94 | 50 |
| 1916 | 48 | 71 | 48 |
| 1917 | 28 | 48 | 71 |
| 1918 | 14 | 62 | 343 |
| Average for 11 years | 30 | 53 | |

Increase due to irrigation ------------------ 23 bushels
Increase due to irrigation ------------------ 77 per cent.

It is correctly remarked in the bulletin in which the foregoing tabulation is published that "the yields are higher than would probably have been the case had the fields (1.60 acre plots) been larger.

The comparative results are, no doubt, the same, i.e., the percentage of increase, due to irrigation, is the same as would have been the case had the fields been larger."

It is also remarked that "on the dry land, the crops have invariably been planted on summer fallowed land, so that, to be really fair in the comparison, the yields on the dry land should be divided by two, for, on the irrigated land, a rotation has been followed and no summer fallowing has been done, that is to say, a crop of some kind has been produced every year on the land."

And that last remark applies, of course, to all irrigated land, a crop of some kind can be produced every year.

It is noticeable, that apart from the years of bumper crops on dry lands, 1915 and 1916, the *average* yield on dry land (30 bushels) is greater than the yield in any individual year, except 1909 (31 bushels).

If the yields from both dry land and irrigated land in 1915 and 1916 are omitted, the averages become 24 and 46 bushels respectively, the increase due to irrigation, 91 per cent., and 22 bushels per acre.

The yields in the irrigated land show a fairly steady increase, omitting 1915 and 1916, except in the year 1910, with 23 bushels per acre.

The year 1910 was one of minimum precipitation throughout: 7.95 inches total, and 4.49 inches during the cropping season.

The year 1918 was another of minimum precipitation, 7.62 inches total, and 4.48 inches during the cropping season: practically the same as 1910.

And "dry" land yields were almost the same in each year: 11 in 1910 and 14 in 1918.

Yet the yield on irrigated land in 1910 was 23 bushels per acre and in 1918, 48 bushels per acre.

It is possible that, in the former year, the irrigation supply was not sufficient, or, that better knowledge of the methods of application had been gained in the interval, though that would be unlikely, as the Experimental Station was wisely directed throughout.

It is a fair conclusion, from all these considerations, that, by irrigation, an increased yield of 23 bushels of wheat can be obtained over the yield from "dry" land, one season with another, covering a long period, and that as a minimum. It will be noted, in the tabulation of comparative results, that the average increase of yield, from 1912 on, is above that—is 28 bushels—and is below that, in two years only, 1912 with 22 and 1917 with 20.

At the low rate of $1 per bushel, that gives a return of $23 per acre upon an increased outlay of $6 per acre.

Under irrigation, agriculture would not be confined to wheat farming. Diversified cropping would speedily be resorted to, as indicated in the other crops of which comparative results are given in the bulletin, oats, barley, peas, and potatoes, all of which show large percentage of increase.

Some general comments in this bulletin are so apt to the present consideration, that no apology is necessary for quoting them here:

> "This diversification [of cropping] means that there will be certain parts of the farm devoted to hay and pasture. It means that our livestock holdings will be vastly increased, and with the carrying of the livestock on the land, the question of an adequate supply of humus on the soil will be solved. This, in itself, will modify, to a great extent, the troubles we are beginning to experience in soil drifting.
>
> "The weed problem will be taken care of to a large extent, because weeds that thrive in grain disappear when the land is seeded down to alfalfa.
>
> "The land, after being seeded down to alfalfa for a few years, is **richer** than ever for the growing of grain, and so the circle is completed, and more stable and permanent conditions are established in our farming operations.
>
> "Comparative yields of alfalfa and timothy are not given, for the reason that the returns from these crops have been so low on the dry land, that it was hardly worth while to tabulate them.
>
> "On the irrigated part of the station, our average yield of cured alfalfa, for the past ten years, has been considerably over **four tons** per acre."

The prospects of adequate return to the farmer for the additional investment are not doubtful, and need not be confined to the particular instances quoted, or, if so, the extreme test can be applied. In 1909, for instance, irrigated land yield of wheat was only 9 bushels greater than dry land yield, and the price of wheat would have been 67 cents per bushel, to return to the farmer the additional investment of $6.00 per acre, only. The irrigated land yield, 40 bushels, in 1909, was also the lowest in the ten-year period, except that of the following year, 1910, the abnormal conditions of which have been referred to. Under irrigation, wheat yield was higher than 40 bushels in 9 years out of 10 records, while dry land yield was lower than 40 in 8 years out of 10—in an average of 16 bushels lower.

At the average or lowest price of wheat in the past ten years, or as the next ten years may be forecast, the farmer would be amply repaid for his additional investment, even including the further allowance of $1.55 per acre per annum, for sinking fund.

That is considering the investment on the least remunerative farming which could be followed under irrigation. The principal advantage following upon irrigation lies in the extension of diversified cropping, in the addition of humus to the soil, the checking of soil drift and reduction of the weed difficulty and the extension of the hay and pasture area, all of which will tend, from the strictly financial view-point, to the steady enhancement of the security behind the bonds, and, from the view-point of the commonwealth, the establishment of a stable and permanent agricultural community.

## ADMINISTRATION ASPECTS

From the preceding analysis, which it has been the effort to make on conservative lines, in all respects, the conclusions are that there would be an assurance of water supply, that the construction features, though of magnitude, are simple in character, that the total cost is reasonable and would be warranted by the increased returns to be secured, in short, that there is no serious engineering or financial problem involved in the enterprise.

The total financial burden of $51.26 per acre, while relatively high in a country in which irrigation is still comparatively in its infancy, would not be considered unusual as the price of a first class water right, in regions where irrigation has been practised for a generation; for example in such districts as Colorado, in which the range of crops is similar to that near Lethbridge (with the addition perhaps of garden and truck farming and sugar beets, and the latter have been raised in Southern Alberta).

Under thoroughly competent and efficient management, with the irrigable land farmed *by irrigation* with ordinary skill and diligence but continuously after water is available for application to the land, the project can be carried to success; to the discharge of the financial obligation; to the profit of the landowner; and to the benefit of the general community and the advancement of agriculture in the Province. But the requisite competence and efficiency must be continuously applied from the beginning of construction to the final discharge of the bonded indebtedness.

The real problem is the administrative problem.

It is an axiom in irrigation that with a sufficient water supply intelligently applied to suitable soil there is profit to the landowner, irrespective of the fortune, good or bad, of the intermediate agency effecting the union of water and land.

The "irrigation district" method, in effect, seeks to place the burden directly on the element certain of profit,—the land and its owner. That process entails consideration of the ability of the landowner to secure the benefit and profit inherent in the undertaking.

It may seem trifling to suggest that the occasional success attending "dry" farming in this district may militate against the future administration of this irrigation enterprise. It will be conceded, however, that if this enterprise is started at all, it must be started on clear recognition of all its problems, and upon the provision of the surest means as far as human foresight can provide to attain the successful result, not alone in the interest of the enterprise itself, but of all that may depend upon its outcome.

There is a danger that, following upon one or more "bumper" crops from natural conditions, such as were secured in 1915 and 1916, the landowner may become weary of the burden entailed in the maintenance of the artificial means employed at considerable outlay, to assure continuance of such "fat" years.

And, from the community which has settled upon these 97,531 acres, in the hope of obtaining a profitable livelihood under these natural "dry" farming conditions, affected as they must have been by the vicissitudes and precarious character of these conditions, must come the leaders who shall care for the expenditure of large sums of money, in works of a character and magnitude to which they have been unaccustomed, and who shall continue, not only to conduct affairs so as to insure the payment alike of principal and interest, but, steadily, to guide and inspire the community to the zealous performance of all the obligations assumed.

Under the provisions of The Irrigation District Act of Alberta, 1915, the sole control of the project, in all respects, is in a Board of Trustees, elected by the landowners.

Under the existing circumstances of this project, as briefly stated above, with a Board of Trustees, composed of men, earnest in effort to improve the agricultural condition of a great area and to better their own position, but unfamiliar with handling large sums of money, with large construction or with irrigation conditions, and, on the other hand, with the Canadian financial world generally unfamiliar with irrigation investments, as a whole, and with such under district management in particular, it is certainly doubtful, if not impossible, that the Lethbridge Northern Irrigation District could be financed solely upon its own merits, granting these to be excellent and the Board of Trustees to be the best obtainable, in all respects. If it was possible to so finance it, it would undoubtedly be on such discount terms that might imperil the prospect of success, or subject the undertaking to heavy handicap, an experience not unusual in pioneer efforts in any line of endeavor.

To these factors adversely influencing the prospects of financing the enterprise, as an "Irrigation District" project, exclusively, the prevailing attitude of the financial world in the United States, at the present time, towards all irrigation securities, and to "Irrigation District" securities particularly, would undoubtedly contribute a further and powerful effect.

Following the enactment, during the past fifteen years, of "Irrigation District" Acts in various Western States, a "boom" in irrigation development occurred, during which many such enterprises, involving large investments in some instances, were promoted. Generally, there was a lack of regard or consideration of the essential requirement of the various elements contributing, even, to a chance of success in irrigation. The inevitable collapse occurred, entailing heavy losses, particularly in projects that had been extensively advertised, with the consequence that all undertakings coming under the general classification of "Irrigation District" Schemes fell into disrepute, from which even well considered projects are now only slowly emerging.

Investigation of the causes of failure would reveal a variety of reasons for lack of success, differing in character with the differing locality and condition, from insufficient water supply to unwarrantable cost of construction, but all contributing to the general disrepute of these securities, merely as such.

In the circles usually depended upon to furnish financial support, a meritorious irrigation project, certainly in a new territory, would wait long for mere consideration at this time, and were credit extended at all, the terms, of discount, interest, etc., would, undoubtedly, reflect the general unfavourable attitude of the investor, and would, as intimated in the foregoing remarks, prove a heavy handicap on the enterprise, in its initial stages.

Provision for a guarantee by the Government of the Province of Alberta introduces the consideration of a far-reaching policy, which compels thoughtful deliberation following upon full realization of all that is involved.

There are, in Southern Alberta, extensive areas that can be fully developed only by irrigation, by the bringing together of the region's resources in water and in land, these two under the control, largely, of the Dominion and Provincial Governments.

The existing agitation for the application of irrigation methods to areas hitherto farmed under "dry" farming, even if such agitation be only temporary in character, may be interpreted as a recognition, by the settlers on the land, of the precarious character of agricultural pursuits under such conditions. The most superficial study of the climatic conditions of the territory, as, for instance Table No. 1, of rainfall, should convince the most hopeful that the barren results of the past two years will recur, with more or less regularity, as they have in the past, and that the "fat" years are too widely separated, either to provide competence or to establish a stable self-supporting community.

In the broad statesmanlike view of the development of the resources of the Province, and the welfare and prosperity of its people, the Governments, Dominion and Provincial, may well realize this, and further realize, that, as has been pointed out in the preceding remarks, those communities by themselves and by virtue of the existing Irrigation District Act, willing as they may be to bear the financial burden, cannot hope unaided to carry out the works without serious financial handicap, while, on the other hand, they may not be trained or naturally fitted to efficiently and economically provide and direct the necessary agencies.

On the other hand, Governmental aid, if granted, must be based on the assurance of the inherent merits of the particular project, and must be set around with safeguards, at least, and, in the best interest of the community, be supplied with instrumentalities, that will not merely protect the financial assistance rendered, but will further the work of development, aid the farmer, and insure the success of every effort to promote community building. The mere guarantee of the bonded indebtedness should not end, but would rather begin, the Government's obligation, which must be continuing and helpful, until, at least, the indebtedness has been fully repaid.

Without some form of guarantee, it is plain, from what has already been said, that full development of the resources of Southern Alberta cannot be secured or will be postponed indefinitely. Such prospect cannot be calmly contemplated by either Dominion or Provincial Government.

If guarantee is given, there may be, *first*, some consideration of the relative extent or character of the contribution to be made by each Government. It is inevitable that, with mutual interest in the development, by control of the necessary resources, water and land, there should be some sharing of the financial burden of the guarantee, in what form or to what extent it is beyond the province of the writer even to suggest.

It is clear, however, in the particular case under consideration, that this District, even with the guarantee of the Government of Alberta, cannot secure the financial requirements without an impairment which the aid of the Dominion Government might obviate. If that view is correct, and if it is within the power and the disposition of the Dominion Government to participate in the development to such extent, it would be regrettable if any minor considerations, from any source, should be permitted to interfere with thus providing, in practical form, a material aid to progress, an aid that might take the form, primarily, of avoiding any discount of required capital, of reducing interest charges, and of providing means for more ready repayment of the indebtedness incurred.

With guarantee granted by either or both of the Governments, a Board, or Commission, must be created to supervise the affairs of the District, during the period of construction and the expenditure of money, at least, and its functions and powers may wisely be extended beyond that period. Such Board would, most naturally, be Branch of the Ministry of Public Works, and, in view of the inevitable extension of its sphere of operations, not confined solely to the construction of works but to the broad field of irrigation possibilities within the Province, should be of continuing character and be composed of men chosen for their special fitness for the particular class of work in contemplation.

It should be small enough to avoid unwieldiness, the selection of its members should be, wholly, in the Government, or Governments, and there should be, at least, three special types of men on the Board, apart from the question of total number, an *engineer*, with knowledge of irrigation, and, quite as important, knowledge of affairs and of men, and of broad training and experience, a *businessman*, and an *agriculturist*, preferably an *agricultural engineer*, also with experience in irrigation.

The function of such Board would be to conduct the affairs of the District, certainly during the period of construction, in all its relations, including the location and design of the works, the award of contracts, and general supervision. That implies the control of the engineering forces and all that affects the prosecution of the work.

The Board of Trustees of the District would thus be shorn of some of the powers conveyed to it under the provisions of The Irrigation District Act of 1915. Under the circumstances, however, the arrangement is not unusual; a guarantor frequently makes such stipulation for the carrying-out of the work under similar conditions, and, in all probability, the Board of Trustees of such Irrigation Districts as are contemplated by the Act, would welcome an opportunity to divest itself of the grave responsibilities incurred in its task.

The abolition of the Board of Trustees is not contemplated, its continued existence is essential, not only for the representation of the landowner in the management of the community's affairs, but for the sense of responsibility which must be imposed upon the individual owners behind the security.

There would be ample scope for the activities of both Boards.

Without entering into detail at this time, it may be suggested that upon the Board of Trustees there would fall, from the inception of the work, important and responsible, if less onerous, tasks, as the securing of rights of way, the arrangement of land assessments, and, later on, the distribution of water, the collection of taxes or assessments, the guidance of the water-user and the missionary work necessary to realization by the landowner of the obligations assumed and the task incumbent on each individual to work out success for himself and for the enterprise.

The two Boards, necessarily, must be harmonious and co-operative. There is entailed the clear definition of the powers conveyed to each to avoid duplication and eliminate possible friction.

And the necessary arrangements will be made in full recognition of the fact, that, accompanying a Government guarantee, there must be Government supervision and control, continued only until such time as the District has shown, beyond doubt, its ability to administer the investment for which its individual members have become responsible. By such time, the Government, or Governments, will have clearly realized that the scope of possible development has materially widened, and will then recognize, what should be clear from the beginning, that the Superior Board must be continuing, and not confined in its composition, either in individual element or general scope, to any one enterprise.

Into the details of the necessary recasting of The Irrigation Act itself, to conform with these general suggestions, if they meet with acceptance and the broad policy is adopted, it may not be appropriate to enter here; but, if desired, it may form the subject for further comment.

While the general conclusions have been presented in the progress of this report, in which I have endeavored neither to magnify the possibilities, nor minimizing the difficulties attaching to what constitutes chiefly, a new departure in Governmental policy, it will be well to summarize these conclusions:

(*a*) That the territory embraced in the Lethbridge Northern Irrigation District, 97,531 acres, needs the application of irrigation for its full development.
(*b*) That there is an assurance of adequate water supply and that the canal system, as designed, is adequate for the irrigation requirements.
(*c*) That the incorporation of the Keho Reservoir, as an adjunct to the system, is recommended as part of the original work.
(*d*) That the lands are well adapted for successful cultivation by irrigation.
(*e*) That the total cost of the necessary canal system is estimated at $3,911,176, at the rate of $40.12 per acre.
(*f*) That the total cost of maintenance and operation is estimated at $171,800 annually, at the rate of $1.76 per acre.
(*g*) That, in order to cover discount on bonds, interest during construction, interest and maintenance and operation charges for one year after completion of construction, and working capital, a bonded indebtedness of $5,000,000, 30 years, at 6 per cent. interest, must be provided, *representing $51.26 per acre.* A sinking fund, to retire bonds, to be created during the last 20 years.
(*h*) That financial burden represents—
For interest --------$3.07 per acre per annum
For maintenance
and operation ----$1.76 per acre per annum
$4.83 per acre per annum
and sinking fund,
in last 20 years---$1.55 per acre per annum *additional*
(*i*) That, with necessary charges for ditching and irrigation added, the extra burden, over natural farming expenses, will be $6.00 per acre per annum in the first 10 years, and that the additional returns secured will warrant that added operating cost.
(*j*) That, upon its own foundation, it is considered doubtful, if not impossible, for the Lethbridge Northern Irrigation District to finance itself, or to do so only by serious impairment of the necessary capital.
(*k*) That a Government guarantee should be accompanied by the creation of a Board, or Commission, as a Branch of the Ministry of Public Works, with broad powers, in view of the probable extension of irrigation development in the Province, and that the Irrigation District Act of 1915 will require recasting, should such policy be adopted.

All of which is respectfully submitted by

GEORGE G. ANDERSON,
*Consulting Engineer.*

**Member, Engineering Institute of Canada.**
**Member, Institution of Civil Engineers.**
**Member, American Society of Civil Engineers.**

# APPENDIX

## Rainfall during the cropping season

| | 1904<br>ins. | 1905<br>ins. | 1909<br>ins. | 1910<br>ins. | 1917<br>ins. | 1918<br>ins. | 1919<br>ins. |
|---|---|---|---|---|---|---|---|
| May | 2.86 | 1.33 | 4.27 | 0.79 | 0.95 | 0.58 | 1.75 |
| June | 1.80 | 2.68 | 0.62 | 0.53 | 1.42 | 0.75 | 0.56 |
| July | 0.96 | 1.44 | 1.98 | 0.09 | 1.37 | 0.85 | 1.06 |
| August | 1.19 | 1.99 | 0.21 | 1.07 | 1.37 | 1.23 | 1.05 |
| September | 0.52 | 0.80 | 0.49 | 2.01 | 0.72 | 1.07 | 2.04 |
| Total | 7.33 | 8.04 | 7.57 | 4.49 | 5.83 | 4.48 | 6.46 |

## Distribution of Irrigation Allowance

| | inches |
|---|---|
| May | 3.32 |
| June | 5.08 |
| July | 4.95 |
| August | 3.04 |
| September | 1.61 |
| Total | 18.00 |

## Addition of Rainfall and Irrigation Allowance

| | 1904 | | | 1905 | | |
|---|---|---|---|---|---|---|
| | Rain inches | Irrig. inches | Total inches | Rain inches | Irrig. inches | Total inches |
| May | 2.86 | 3.32 | 6.18 | 1.13 | 3.32 | 4.45 |
| June | 1.80 | 5.08 | 6.88 | 2.68 | 5.08 | 7.76 |
| July | 0.96 | 4.95 | 5.91 | 1.44 | 4.95 | 6.39 |
| August | 1.19 | 3.04 | 4.23 | 1.99 | 3.04 | 5.03 |
| September | 0.52 | 1.61 | 2.13 | 0.80 | 1.61 | 2.41 |
| Total | 7.33 | 18.00 | 25.33 | 8.04 | 18.00 | 26.04 |

| | 1909 | | | 1910 | | |
|---|---|---|---|---|---|---|
| | Rain inches | Irrig. inches | Total inches | Rain inches | Irrig. inches | Total inches |
| May | 4.27 | 3.32 | 7.59 | 0.79 | 3.32 | 4.11 |
| June | 0.62 | 5.08 | 5.70 | 0.53 | 5.08 | 5.61 |
| July | 1.98 | 4.95 | 6.93 | 0.09 | 4.95 | 5.04 |
| August | 0.21 | 3.04 | 3.25 | 1.07 | 3.04 | 4.11 |
| September | 0.49 | 1.61 | 2.10 | 2.01 | 1.61 | 3.62 |
| Total | 7.57 | 18.00 | 25.57 | 4.49 | 18.00 | 22.49 |

| | 1917 | | | 1918 | | |
|---|---|---|---|---|---|---|
| | Rain inches | Irrig. inches | Total inches | Rain inches | Irrig. inches | Total inches |
| May | 0.95 | 3.32 | 4.27 | 0.58 | 3.32 | 3.90 |
| June | 1.42 | 5.08 | 6.50 | 0.75 | 5.08 | 5.83 |
| July | 1.37 | 4.95 | 6.32 | 0.85 | 4.95 | 5.80 |
| August | 1.37 | 3.04 | 4.41 | 1.23 | 3.04 | 4.27 |
| September | 0.72 | 1.61 | 2.33 | 1.07 | 1.61 | 2.68 |
| Total | 5.83 | 18.00 | 28.83 | 4.48 | 18.00 | 22.48 |

**Addition of Rainfall and Irrigation Allowance—Continued.**

| | | 1919 | |
|---|---|---|---|
| | Rain inches | Irrig. inches | Total inches |
| May | 1.75 | 3.32 | 5.07 |
| June | 0.56 | 5.08 | 5.64 |
| July | 1.06 | 4.95 | 6.01 |
| August | 1.05 | 3.04 | 4.09 |
| September | 2.04 | 1.61 | 3.65 |
| Total | 6.46 | 18.00 | 24.46 |

**Comparison of Rainfall plus Irrigation Allowance with Rainfall of 1916 during cropping season.**

| | 1904 | 1905 | 1909 | 1910 | 1917 | 1918 | 1919 | Rainfall only 1916 |
|---|---|---|---|---|---|---|---|---|
| May | 6.18 | 4.45 | 7.59 | 4.11 | 4.27 | 3.90 | 5.07 | 3.77 |
| June | 6.88 | 7.76 | 5.70 | 5.61 | 6.50 | 5.83 | 5.64 | 3.54 |
| July | 5.91 | 6.39 | 6.93 | 5.04 | 6.32 | 5.80 | 6.01 | 3.33 |
| August | 4.23 | 5.03 | 3.25 | 4.11 | 4.41 | 4.27 | 4.09 | 2.97 |
| Sept | 2.13 | 2.41 | 2.10 | 3.62 | 2.33 | 2.68 | 3.65 | 4.66 |
| Total | 25.33 | 26.04 | 25.57 | 22.49 | 23.83 | 22.48 | 24.46 | 18.27 |

## Notes on Tables 6, 7, 8 and 9.

Applying the canal loss of 34 per cent to the *water diverted* from the stream, i.e., 800 second feet, as the upper section of the canal would be additionally large to deliver that *net* quantity below the siphon crossing, the delivery results would be slightly different.

In average years, there would be 800 second feet flowing continuously for 153 days, a total of 244,800 acre feet, less canal loss 34 per cent. of that amount, 83,232 acre feet, leaving 161,568 acre feet for a total requirement of 146,296 acre feet—97,531 acres at 1.5 acre feet. There would thus be a surplus of 15,272 acre feet, throughout the season.

In years of minimum flow there would be—

| | |
|---|---|
| 800 second feet for 76 days — 1st and 2nd period | 121,600 ac. ft. |
| 584 second feet for 36 days — 3rd period | 42,048 ac. ft. |
| 320.6 second feet for 41 days — 4th period | 26,289 ac. ft. |
| | 189,937 ac. ft. |
| Less canal loss 34 per cent | 64,578 ac. ft. |
| | 125,359 ac. ft. |

Against a total requirement of 146,296 acre feet, a shortage of 20,937 acre feet which would have to be drawn from the reservoir, which would be full at the beginning of the season and, from withdrawals and losses, and the fact that in the first two periods some excess in canal delivery would not be available for storage in the reservoir, already full, reduced possibly as low as 6,000 acre feet at the end of the season. And, again, even with the small amount in storage at the close of September, it could be filled to capacity prior to the next season's heavy draft.